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REVIEWS

Use of robotics in broiler production systems: a relationship between technology, environment and production

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Abstract
In poultry farming, robotics is represented by robotic models which perform different functions. Among these functions, ambience is one of the most critical, as the aviary is an artificial environment which needs to present all the necessary conditions for the thermoregulatory maintenance of animals. This paper is a review of the technological status of robotics, ambience and associated technologies in modern poultry farming. A combination of two methodological literature review techniques (systematic and bibliometric) was used to identify how robotics is being used in poultry farming, its relationship with the environment and trends. Thresholds for various ambience parameters (such as thermal, chemical and physical) were evaluated based on data from the literature. Results showed several robots which perform different functions in poultry houses and the environment is characterized as just one of the possibilities and that presents deficiencies due to the lack of high-performance communication, thus preventing assertive decision-making. Most of the research was carried out in the last four years, with China, the United States and the United Kingdom being the countries which published the most. The trends are that computer vision is the most exploited technology in robots related to production automation (*e.g.* handling and navigation) and artificial intelligence and the internet of things related to robots in the production system (*e.g.* ambience and information management).

Keywords Robotics in poultry farming · Technology trends in poultry farming · Smart poultry farming · Bibliometric review robotic poultry

Introduction and contextualization

Modern poultry farming, guided by losses and costs reduction, uses several technological components of Industry 4.0 in order to increase productivity of the production systems (Ahmed et al. 2024). The drivers for this demand are the growing demographic increase in the population, which results in an increasing consumption of food (Wakchaure et al. 2023; Silva et al. 2023) and the growth of international trade combined with a greater need for intensive agricultural ecosystems (Bui et al. 2024; Dennis et al. 2020).

Among the technological components, robotics stands out as it is adaptable to farms due to its versatility of use in different conditions. This allows the use of intelligent automation in animal production due to its technological properties such as: perception, reasoning, learning, communication, planning and execution of tasks (Ren et al. 2020; Cheng et al. 2023). Perspectives and trends indicate that robotics will be increasingly expanded in animal production, reducing human interventions in physical activities and promoting greater precision in production rates due to effective assessments based on real-time data (Mansilha et al. 2019; Abreu et al. 2020; Usher et al. 2017).

Currently, data collection methods are relatively simple and not very robust, demonstrating that high-performance

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communication (characterized by being in real time and by strong interaction between human/robot) has not yet been carried out to its full capacity (Ren et al. 2020). This fact expands the vast possibility of research which includes precision ambience from this perspective, enabling robots to collect and transmit productive data for complex analyzes through mathematical modeling which determine levels of thermal comfort and health in real time, in addition to visualization of metrics on the productive and health status of flocks for assertive decision-making (Phiri et al. 2018). Furthermore, there is still the challenge of building robotic designs which are applicable to different poultry environments (compatible with the production scale in terms of size, movement, husbandry systems, environmental models, etc.) and which can respect the birds' well-being (Zhang et al. 2022).

This review presents a historical analysis of the last ten years and the current state of robotics in poultry farming in terms of environmental factors which influence production rates using technological tools related to robotics (automation and electronic components [sensors and actuators]). From this research, it will be possible to understand which trends are in evidence or out of use in this technological scenario, in addition to establishing a status quo for robotics in poultry farming worldwide.

Theoretical foundation

Poultry farming is characterized by the production of low-cost animal protein for human consumption. Chicken presents, in a short space of time, high feed conversion through rapid weight gain while maintaining uniform growth, making it an appreciated product on the international market (Qi et al. 2023). These traits were obtained through the systematic evolution of genetic improvement from the crossing of several breeds of birds to obtain commercial strains with great performance in meat production such as Cobb, Ross, Arbor, Acres, Hubbard, among others (Lopes 2011; Fulton 2012; Hartcher and Lum 2019).

Poultry environment

The artificial environment generated in an aviary must meet all the needs of animal homeostasis. Several authors state that the main environmental variables which must be controlled in this artificial environment are: thermal (air temperature, relative humidity and wind speed); physical (thermal radiation and light level); chemical (presence of contracted gases [ammonia, carbon monoxide and carbon dioxide] and dust level); and biological (individuals and microorganisms) (Melak et al. 2024; Muniz 2019; Silva et al. 2023; Gundim et al. 2015; Schiassi et al. 2015; Figueira et al. 2014; Moreira and Salsa 2014; Campos 2000).

Thermal ambiance

The chicken is an animal which is very sensitive to thermal variations, especially in the early stages of its life, as the physiological mechanisms for thermoregulation have not yet fully developed during this period. Therefore, the aviary must provide a safe and controlled environment in terms of air temperature and humidity, which guarantees the ideal development of the animal. Regarding relative humidity, Ross (2018) and Jong et al. (2012) state that the first three days of an animal's life are crucial for its development, and during this period humidity must be controlled between 60–70% and, at more advanced ages, excessive humidity can cause damp beds and cause health problems to the animal. However, during chicken development, Jong et al. (2012) state that humidity values below 50% can contribute to an increase in particles in the air, thus favoring the emergence of respiratory problems. Abreu and Abreu (2011) and Macari and Furlan (2001) consider any variation in humidity below 40% or above 80% to be critical for the entire development phase of the animal (Table 1).

Regarding dry air temperature, Moura et al. (2010) state that its control must be prioritized during all phases of the animal's rearing, with each phase presenting specific values which must be guaranteed due to the animal's physiological mechanism. These values, when not respected, cause thermal stress in animals and changes in their physiological response, such as peripheral vasodilation with loss of non-evaporative heat, increased respiratory rate with excessive loss of carbon dioxide, and increased blood pressure (Souza et al. 2013; Silva et al. 2023; Gomes et al. 2015). Furthermore, Macari and Furlan (2001) states that there is a difference between feed and water consumption for weight gain in chicks, of up to seven days, when reared at temperatures of 20–25ºC compared to others raised at temperatures of 32–35ºC. Thus, for a chicken in the early stages of its life, the recommended temperature should be close to 32ºC and gradually decrease by 1ºC every two days until in the third week of rearing it is around 20ºC with variations of ± 2 °C. However, there are variations which are tolerated by the animal, for example, excessive temperature can be tolerated when relative humidity is low, but intolerable when humidity is high because it causes condensation inside the aviary (Moura et al. 2010). Mickelberry et al. (1966) and Maxwell and Robertson (1998) state that temperatures higher than 35ºC, in the initial phase, can cause hyperthermia followed by dehydration to the birds, resulting in reduced feed consumption and delayed growth; and that excessively low

Table 1 Temperature and humidity references for broilers

Relative humidity (%)				Air temperature (ºC)			
Authors	Week	Min	Max	Authors	Week	Min	Max
Macari and Furlan (2001)	1st	≈ 60.0		Macari and Furlan (2001)	1st	33.0	35.0
	2nd				2nd	30.0	33.0
	3rd				3rd	27.0	30.0
	4th				4th	24.0	27.0
	5th				5th	21.0	25.0
	6th				6th	21.0	24.0
Tinôco et al. (2008) Macari and Furlan (2001) Medeiros (2015)	1st	60.0	70.0	Tinôco et al. (2008) Macari and Furlan (2001) Medeiros (2015)	1st	32.0	34.0
	2nd				2nd	28.0	32.0
	3rd	50.0	70.0		3rd	18.0	28.0
	4th				4th	18.0	26.0
	5th				5th	18.0	26.0
	6th				6th	18.0	26.0
Abreu and Abreu (2011)	1st	60.0	70.0	Abreu and Abreu (2011)	1st	32.0	35.0
	2nd				2nd	29.0	32.0
	3rd				3rd	26.0	29.0
	4th				4th	23.0	26.0
	5th				5th	20.0	23.0
	6th				6th	20.0	20.0
Cobb (2019)	1st	30.0	50.0	Cobb (2019)	1st	32.0	33
	2nd	40.0	60.0		2nd	29.0	30.0
	3rd	50.0	60.0		3rd	27.0	28.0
	4th	50.0	65.0		4th	24.0	26.0
	5th	50.0	70.0		5th	21.0	23.0
	6th	50.0	70.0		6th	19.0	21.0
Campos (2000) Ross (2018)	1st	60.0	70.0	Rosa et al. (2012)	1st	31.0	32.0
	2nd				2nd	28.0	30.0
	3rd				3rd	26.0	28.0
	4th	50.0	60.0		4th	24.0	26.0
	5th				5th	22.0	24.0
	6th				6th	20.0	22.0
Relative Humidity (average)	1st	54.0	62.5	Air Temperature (average)	1st	32.0	33.8
	2nd	56.0	65.0		2nd	28.7	31.4
	3rd	56.0	65.0		3rd	25.0	28.6
	4th	54.0	63.8		4th	21.3	26.6
	5th	54.0	65.0		5th	19.5	24.6
	6th	54.0	65.0		6th	18.8	22.6

Source: study authors

temperature levels, still at this stage, can cause cases of hypothermia with worsening to pulmonary hypertension syndrome (ascites) (Table 1).

Chemical ambience

Air exchange in the poultry house, when carried out incorrectly, causes inadequate concentrations of carbon monoxide, carbon dioxide and ammonia, thus reducing oxygen concentrations and favoring the incidence of lung and genetic diseases (Qi et al. 2023; Dornelas et al. 2023; Oliveira et al. 2020; This is confirmed by the fact that carbon dioxide is denser than oxygen, remaining stable at the birds' level, making it difficult for them to breathe and increasing mortality rates (Oliveira et al. 2020). Carbon monoxide also causes similar effects in animals, with Wathes (1999) recommending a limit of 10 ppm for any phase of the animal (Table 2).

Ammonia levels are related to the variables: temperature, relative humidity, ventilation rate, diet, moisture content and type of litter, animal density and bird age. It is produced by the microbial decomposition of elements in the litter (JONG et al. 2012) and several authors (Owada 2007; Jong

Table 2 References of gases in the air for broiler chickens

Gas	Authors	Reference
Carbon monoxide (CO)	Wathes (1999)	maximum 10 ppm
	Jong et al. (2012)	between 14 and 35 ppm
	Cobb (2019)	lower than 10 ppm
	HFCA (2013)	between 14 and 50 ppm
	CIGR (2002)	maximum 10 ppm
	Average	16,09 ppm
Ammonia (NH_3)	AHA (2012)	maximum 25 ppm
	Sampaio et al. (2005)	maximum 20 ppm
	Miragliotta (2005)	maximum 20 ppm
	Campos (2000)	maximum 15 ppm
	Cobb (2019)	lower than 10 ppm
	OWADA (2007)	maximum 5 ppm
	Average	15 ppm
Carbon dioxide (CO_2)	Cobb (2019)	lower than 3000 ppm
	Ponciano et al (2011)	up to 3000 ppm
	Ross (2018)	lower than 3000 ppm
	HFAC (2009)	up to 3000 ppm and never exceed 5000 ppm
	Average	3000 ppm
Dust (PM 10)	Wang et al. (2023)	between 1000 and 1500 μg/m^3
	Aarnink et al. (2009)	up to 1073 μg/m^3
	Winkel et al. (2016)	from 1280 to 3362 μg/m^3
	Average	from 1073 to 3362 μg/m^3

Source: study authors

et al. 2012; Aha 2012; Oliveira et al. 2020; Qi et al. 2023; Dornelas et al. 2023) state that concentrations above 5 ppm can already cause health problems in animals. For example, concentrations above 10 ppm cause lung damage and 50 to 75 ppm decrease body weight and double the mortality rate (Table 2).

High levels of carbon dioxide can cause negative effects in adult chicks and chickens such as panting, anoxia, reduced feed intake and reduced growth (Dornelas et al. 2023; Oliveira et al. 2020). Furthermore, they favor the increase in respiratory diseases, significantly alter the productive indices of birds (Abreu and Abreu 2011) and above 3500 ppm cause ascites (Ross 2018) (Table 2).

Dust in the air, associated with other gases, affects the respiratory tract directly and is a vehicle for the transmission of diseases by bacteria or viruses. It is characterized as solid particles (diameter between 1 and 150 microns [μ]) which once suspended in the air, even when stationary, do not diffuse (Miragliotta 2005; Aarnink et al. 2009; Winkel et al. 2016; Wang et al. 2023). They are produced by solid material and are suspended in the air resulting from a set of elements present inside the aviary such as feather remains, skin scales, feces, food and especially the composition of the litter (Jong et al. 2012; Andrade 2017). Dust is measured according to its granularity and is divided into groups of inhalable and respirable particles (Hartung and Seedorf 1999). These particles can be measured simply as respirable dust or according to their granularity (PM < 10 μg/m^3), all of which are harmful to the health of chickens and humans. As a measurement, the PM (Particulate Matter) micron unit of up to 10 microns is used.

Particles smaller than 10 microns are of greatest concern as they can easily pass through the nose and throat and reach the lungs, causing serious respiratory illnesses (Resende 2007). However, Winkel et al. (2016) states that there are uncertainties about the real rates of PM emission in poultry farms. Several studies (Naas et al. 2007; Aarnink et al. 2009; Jong et al. 2012; Andrade 2017; Winkel et al. 2016; Wang et al. 2023) present different forms of measuring dust inside the aviaries, each one presenting different results as they always depend on the type of aviary, the quality of the litter material, the humidity present in the litter, the temperature and humidity of the air, the ventilation flow of the aviary, the age of chickens and litter age (Table 2).

Physical environment

Light directly affects production rates, for example low light levels in the final weeks (< 5 lx) make animals produce lower rates of sensible heat (Naas et al. 2007). The intensity of light

Table 3 Brightness references for broiler chickens

Author	Reference
Figueira et al. (2014)	Minimum 20 lx (during the entire rearing)
Jong et al. (2012)	Minimum 10 lx (during initial weeks) Ideal 20 lx (following weeks)
Cobb (2019)	25 lx (at bird height) 5–10 lx (2nd week onwards)
Oliveira et al. (2006)	20 lx (first week) 10 lx (following weeks)
Ross (2018)	30–40 lx in the first week 5–10 lx in the following
Median	First week: minimum 20 lx Subsequent weeks: 5 −10 lx

Source: study authors

in the aviary must be evenly distributed throughout the aviary and changes in light rates can affect the growth of the animals' eyes, causing variations in air temperature, causing animals to cluster in regions with lower levels of light (Faustino et al. 2021), an increase in lesions due to dermatitis as low light intensity can reduce the animals' locomotor activity and lead to the incidence of contact dermatitis and locomotor disorders (Cristo et al. 2017; Souza and Molento 2015), reducing natural activities and behaviors; however, mainly impacting the physiological rhythm, as the bird does not notice when it is day or night (Cobb 2019; Ross 2018) (Table 3).

Robotics in industrial poultry farming

The current technological development scenario favors the application of robotics in poultry farming due to the development of Information Technology products (hardware and software) which are easily adaptable to different conditions of use (Ren et al. 2020; Vroegindeweij et al 2018; Raja 2024). In this way, extensive research is being carried out in order to assist agricultural production such as mobile robots, autonomous vehicles, drones, robotic arms, etc. (Zhang et al. 2022).

Specifically, examples of the application of avian automation applicable to robotics are: environmental monitoring (Gasmetric 2016; Ren et. al 2020), animal behavior and health monitoring (Kim et al. 2021; Chen et al. 2023), egg harvesting (Li et al. 2020; Fei et al. 2023), incentives for animal movement (Poultry Patrol 2019), sanitation of beds, drinking fountains and feeders (Feng and Wang 2020; Ren et al. 2020; Lin et al. 2023).

The use of robots which work in poultry farming is referenced by the authors: Vroegindeweij et al. (2018) developed an autonomous robot (called PoultryBot – Fig. 1A) with the ability to move around an aviary carrying out the activity of collecting eggs; Ren et al. (2020) presented two robots which are used commercially in poultry production: OctopusRobot (Fig. 1B), for health and welfare inspection of chickens, and ChickenBoy (Fig. 1C), a suspended robot capable of continuously inspecting health and animal welfare; the Rabaud company developed Lavicole (Fig. 1D), a robot specialized in cleaning and disinfecting poultry houses (Lavicole Robot 2020); the Gasmetric company produced a robot with the same name (Fig. 1E) which is capable of carrying out measurements of harmful gases in poultry farms (Gasmetric 2016); and the Tibot Technologies company developed Spoutnic Nav (Fig. 1F) with the functions of stimulating bird movement and turning the litter (Spoutinic Nav 2016).

The documentation which details the robots is often not very expressive. Out of the six robots mentioned in Fig. 1, only three have websites which detail their operations and functionalities. Table 4 presents the details of the functionalities of these robots in a comparative way.

Recent research on the use of robotics in animal production (Chen et al. 2023; Fei et al. 2023; Lin et al. 2023) shows the countless possibilities that can be explored. In poultry farming specifically, this has been made possible and intensified due to technological advances in the chain and due to the increased demand for the consumption of a cheap and quickly produced protein. The prospects are that robotics will be increasingly expanded, reducing human interventions in physical activities and having greater precision in production indicators through effective assessments based on real-time data monitored by robots.

Limitations, challenges, ethical aspects and implications in developing countries of robotics in poultry farming

Robotics in poultry farming presents numerous opportunities for enhancing efficiency and animal welfare, but it also faces several limitations, challenges, and ethical considerations. Shi et al. (2024) and Ren et al. (2020) claim that the technological limitations are caused by the need for technical and, consequently, the operation and maintenance of robots require knowledge that breeders may not have become necessary require professional technical support that could greatly increase the operational cost of the robot in the aviary. And in technological view, Ren et al. (2020) states that robots in aviary are limited by the need for advanced machine capabilities (such as perception, reasoning, and task execution) that are directly affected by the environment and conditions of poultry breeding (high humidity, temperature, dust levels and gases such as ammonia) which can therefore damage or shorten the lifespan of robotic sensors and actuators. Shi et al. (2024) complements by stating which does not possible the construction of standardized but highly customized robots for each type of task execution increasing the complexity and cost of technical implementation.

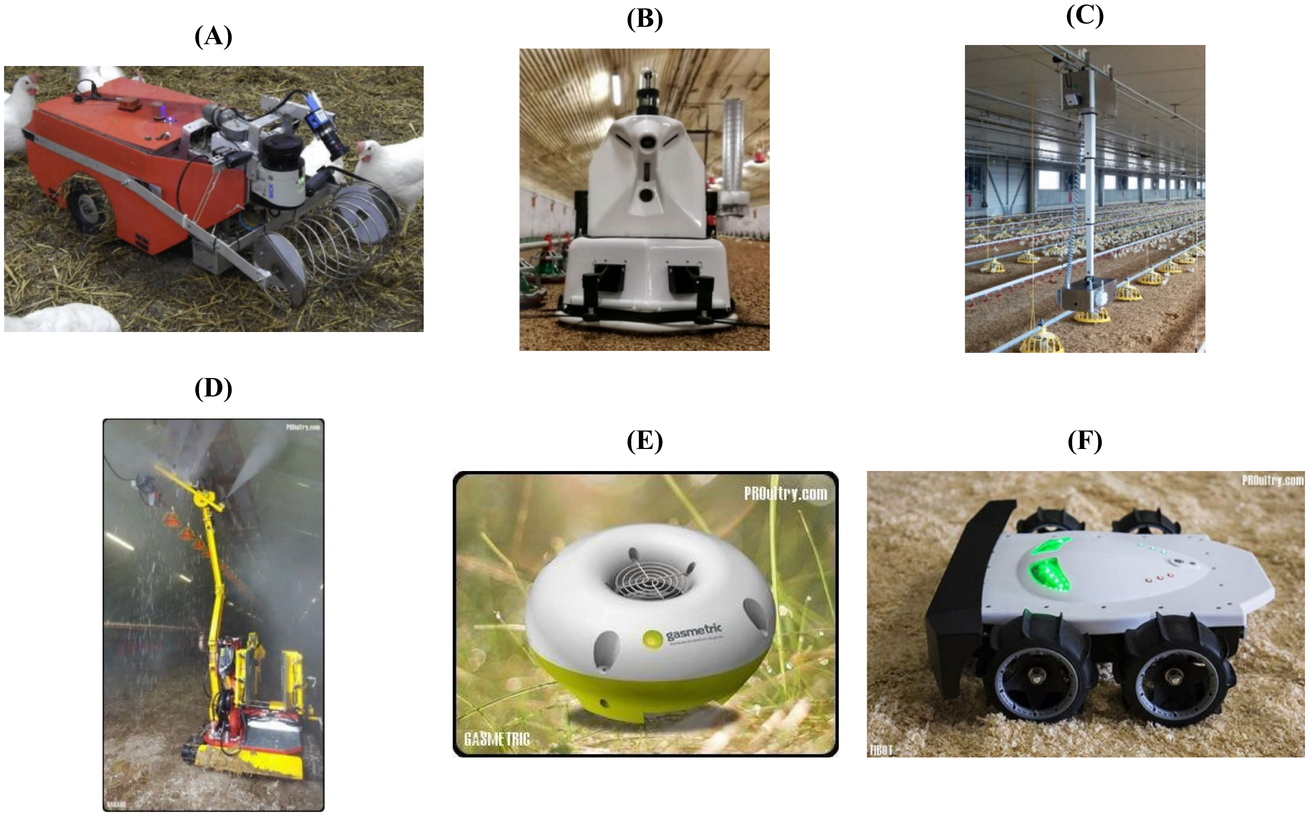


Fig. 1 Robots used in poultry farming: PoultryBot (**A**), OctopusRobot (**B**), ChickenBoy (**C**), Lavicole (**D**), Gasmetric (**E**) and Spoutnic Nav (Source: Gasmetric 2016; Spoutinc 2016 Vroegindeweij et al. 2018; Ren et al. 2020; Lavicole Robot 2020)

This way the investment required for implementing robotic systems in poultry farming is high, what can become a barrier for widespread adoption because includes costs related to the technology, the integration of these systems into existing farming operations, technical support, maintenance of robots, training and technological assistance to producers' poultry breeding (Shi et al. 2024; Sajid et al. 2024). Rosa et al. (2012) states that a culture of continuous learning must be promoted to adjust the producers' to the technological landscape due to the presence of the robot and its systems in the production of poultry that promote efficiency while at the same time upholding strict animal care and environmental stewardship standards. In addition, there is the challenge of concerns about safety and energy consumption. Sajid et al. (2024) and Brittain et al. (2020) states that one should be concerned about the safety of using robots in close proximity to animals and how much this influences the well-being of the animals; Zhang et al. (2022) states that the movement of the robot around the poultry house must be very well planned as it is crucial to minimize energy consumption, which remains a challenge in optimizing robotic operations in poultry farms.

In relation to ethical aspects Özentürk et al. (2024) states that animal health and welfare must be considered because while robots have the potential to improve animal welfare by reducing stress and ensuring better living conditions, there is a need to carefully manage robot-animal interactions to avoid negative impacts on the animals ' well-being (Essien and Job 2024). Several studies (Balthazar et al. 2024; Parajuli et al. 2020; Vroegindeweij et al. 2018) discuss the importance of analyzing the robot's movement in the aviary and determining escape speeds compatible with animal welfare. And, furthermore, Sajid et al. (2024) states that the use of smart sensors and data analytics in poultry farming raises concerns about data privacy and the ethical use of collected data.

Therefore, it is understood that robotics in poultry farming offers significant potential to enhance efficiency, sustainability, and animal welfare. However, several challenges hinder its widespread adoption in developing countries. Shi et. al. (2024) complements that ensuring the safety of both animals, robots and information of system, along with maintaining these all hardware's and software's, poses significant challenges because it includes addressing potential safety concerns and the need for constant maintenance, which can be difficult in resource-limited settings (roads with difficult access, farms without satisfactory internet access, qualified

Table 4 Functionalities and architecture details of poultry farming robots

Robot x Functionality	ChickenBoy (Faromatics)	Octopus Poultry Safe (Octopus Robots)	SPOUTNIC (Tibot Technologies)
Format	Suspended	Terrestrial	Terrestrial
Autonomous movement	Yes	Yes	Yes (can be programmed)
Assisted movement	No	Yes	No
Beacon movement	No	No	Yes
Treats movement stress	No (suspended)	Yes	Yes
Collision treatment	No (suspended)	Yes (repel animals away)	Yes (for stationary objects)
Route programming	Yes	Yes	Yes
Rechargeable (standalone)	Yes	Yes	No
Emits sound/light stimuli	No	No	No
Locates load source on its own	No	Yes	No
Analysis in three dimensions (x,y,z)	Yes	No	No
Vision (visible)	Yes	No	No
Vision (thermal)	Yes	No	No
Video streaming	Yes	No	No
Detects presence of people	Yes	No	No
Sound Analysis (vocalization)	Yes	No	No
Sound Analysis (output)	Yes	No	No
Audio streaming	Yes	No	No
Analysis of Environmental Conditions: Temperature	Yes	Yes	No
Analysis of Environmental Conditions: Relative Humidity	Yes	Yes	No
Analysis of environmental conditions: Carbon dioxide—CO_2	Yes	Yes	No
Analysis of environmental conditions. air speed	Yes	No	No
Detects sound (noise)	No	Yes	No
Detects brightness intensity	No	Yes	No
Detects health anomalies	Yes	No	No
Detect dead birds	Yes	No	No
Anomalies in poultry farm equipment	Yes	No	No
Bed anomaly detection	Yes	No	No
Bed treatment (scarifier)	No	Yes	No
Environmental sanitation (aerosol)	No	Yes	No
Vaccine diffuser (aerosol)	No	Yes	No
Extension slots	Yes	Yes	Yes
Encrypted data	Yes	No	No
SMS alert	Yes	Yes	No
Uses Wi-Fi (real-time internet access)	Yes	Yes	Yes
Web Monitoring System	Yes	No	No
Uses Artificial Intelligence	Yes	Yes	No
Modularizable	No	Yes	Yes

Source: study authors

technical professionals). Overcoming these barriers will require targeted investments, technological advancements, and comprehensive training programs that go beyond the possible resources of farmers but of investments by the local government and private initiative.

Materials and methods—bibliometric review

The methodological proposal for this study was to conduct a survey through the combination of two approaches (Colombino et al. 2021; Rejeb et al. 2022):

a) Literature review: obtaining the basis of the environment for broiler chickens and the definition of a set of key words that relate chickens, the environment and robotics; and
b) Bibliometric analysis: analyze and quantify research results in order to evaluate the evolution of robotics in poultry farming.

The combination of these two approaches aimed to substantiate the state of the art of ambience in broiler chicken production and generate a list of articles which enabled the elaboration of a set of keywords divided into two domains: broiler production system and robotics technologies; the first aimed to create a set of common terms to scientific publications and the second to robotics associated with technologies which support direct application in broiler chicken production. The union of these domains created restrictions which made it possible to find exclusive research articles on robotics and broiler chickens.

The chosen keywords were used in the advanced search tools of Scopus and Web of Science. The technical notation (syntax) of each tool was used and Boolean logic was adopted as an algebraic structure to refine searches (queries) through their logical operators. The results were extracted in Comma Separated Values (CSV) format and all existing metadata were chosen as a response filter for the records. Then the two results (Scopus and Web of Science) were grouped and debugged to exclude redundancies and duplicates using the R programming language in the R Studio environment (version 2023.12.1 Build 402) (Pereira 2022). Quantitative and qualitative analyzes were carried out in the Biblio Shiny package using R Studio. Figure 2 presents a graphic summary of the methodology.

Literature review

The literature review was determined with the following question: "How have robotics been used in poultry farming as a tool to support the environment?" and this made it possible to identify a set of articles that obligatorily had in their title or summary the words "poult*", "robo*" and "(ambience or environment) and "poultry farm*" regardless of whether they covered other production animals or whether poultry farming referred to the production of meat or eggs. From this, all the keywords of these articles were catalogued for execution in the subsequent stage.

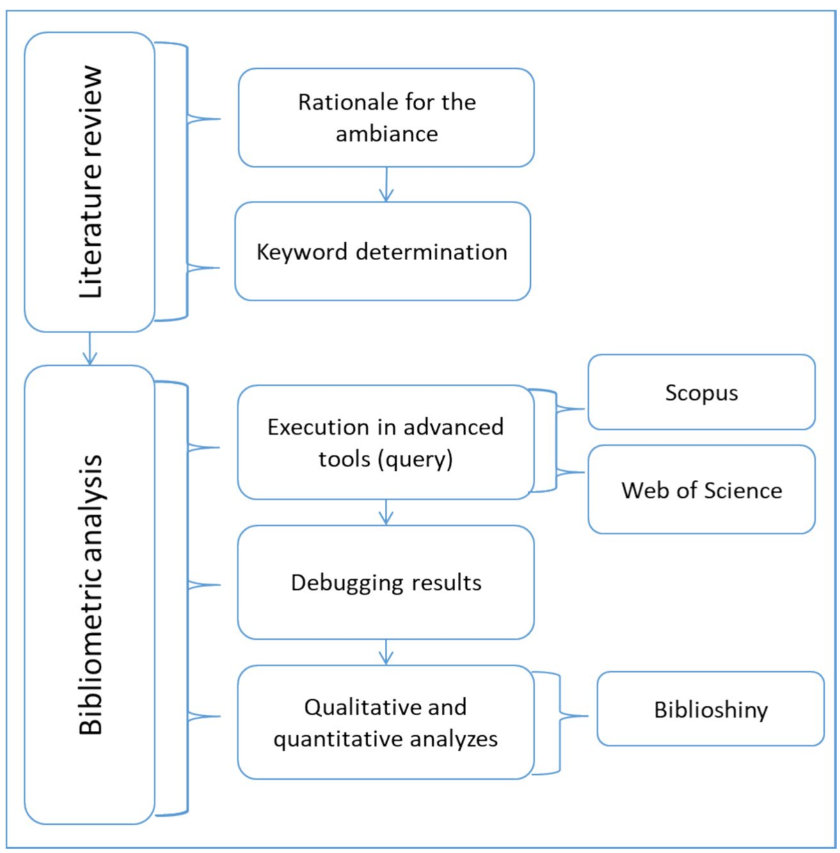


Fig. 2 Graphic summary of the work methodology. Source: study authors

Determination of "Keywords"

A set of keywords was created based on assumptions of domain and technological words. Domain are keywords resulting from the context of the production and technological system resulting from the possibilities of information technology which can be applied to the production system. The method for determining these keywords based on reading the keywords of the articles obtained in the literature review and the successive refinement technique determined a list as a final result of the words useful for bibliographic research.

Database

Two databases of abstracts and citations of articles for academic newspapers and magazines were chosen: Scopus and Web of Science. The decision to choose these two databases was based on the fact that both have a high level of research coverage and a combination of results which determines information that can be complementary, equivalent or exclusive. Two "queries" were executed identically, but in a specific syntax, in each database. The results were grouped and analyzed in the R language to determine redundant results with the intention of eliminating duplicates (Pereira 2022). This enabled processing the obtained data, excluding replicated results, thus maintaining the integrity of information that is self-completed through these databases.

Qualitative and quantitative analyzes

The results were analyzed according to the expressiveness and temporality of the keywords. In this way, the objective was to analyze the frequency, impact and importance of the keywords in the context of poultry farming.

Results

The bibliographic review was carried out on the Google Scholar search platform using the query: ("poult*" OR "chicken broiler") AND ("robo*") AND (("ambience poultry farm") OR ("ambient poultry farm")) and results from the last 10 years (2014–2024) were used. Google Scholar was used only to identify the main keywords from the articles found. The result presented 181 articles whose titles and abstracts were analyzed and 24 articles were excluded because they did not go into depth on robotics. Of the 157 resulting articles, the keywords were analyzed and a list was generated based on two domains: robotics technologies and broiler production system. The results are presented in Table 5.

Table 5 Business domain keywords (broiler chickens)

Robotics technologies	Broiler production system
Artificial Intelligence	*fowl*
Agricultural robotics	*poult*
Automation	*poultry*
Decision suport	*Aviary*
Industrial robots	*aviary poultry house*
Intelligent Analysis	*Poultry houses*
Precision feeding system	*Poultry housing*
System integration	*welfare*
Technology	*Precision livestock farming*
automatic sensing	*Smart poultry management*
automation trends	*unmanned poultry houses*
machine capabilities	*poultry production operations*
technology adoption	*Poultry production systems*
Technology Focussed	*Poultry Sector*
remote monitoring	*Stress detection*
autonomous robot navigation	*health and welfare*
Internet of Things	*Livestock Breeding*
IOT	*livestock production*
Mobile monitoring	*environmental impact*
Mobile robotics	*Automation of poultry farm*
Robô	*Controlled environment*
Robot	*Improving Bird Welfare*
Robotics	*Improving Poultry Welfare*
Sensor	*smart agriculture*
smart broiler robot	*Electronic Chickens*
Smart sensors	*Robot for Livestock Breeding*
Camera	*Robotics in agriculture*
Control chart	*broiler chicken*
image analysis	
Probabilistic localisation	

Source: study authors

The set of keywords was analyzed and it was noticed that many of the words were umbrella concepts for both the production system and information technology. In this way, the keywords were grouped hierarchically from the broadest concept to the most specialized (Table 6).

The hierarchy allowed us to understand which keywords were repeated or had variations and which could be concatenated into a single word. In robotics technologies it was noticed that robo (robotic, robot, robots, robot, autonomous robot navigation, mobile robotics, etc.) was the most frequent word and that many other terms were dependent on this keyword (such as sensor always appeared when there was robot); in broiler chicken production systems it was noticed that the word poultry (poult, poultry production, aviary poultry, etc.) was the most

Table 6 Hierarchization of keywords

Robotics technologies	
Technology	
Automation	
Robô	*Artificial Intelligence*
agricultural robotics	*intelligent analysis*
industrial robots	*decision suport*
automatic sensing	*precision feeding system*
automation trends	*system integration*
machine capabilities	
remote monitoring	
technology adoption	
technology focussed	
autonomous robot navigation	
Internet of Things	
IOT	
mobile monitoring	
mobile robotics	
robô	
robot	
robotics	
sensor	
smart broiler robot	
smart sensors	
camera	
control chart	
Broiler production system	
Chicken	*Precision livestock farming*
fowl	*smart poultry management*
poult	*unmanned poultry houses*
poultry	*poultry production operations*
aviary	*stress detection*
aviary poultry house	*health and welfare*
poultry houses	*Livestock Breeding*
poultry housing	*livestock production*
welfare	*environmental impact*
poultry production systems	*automation of poultry farm*
poultry Sector	*controlled environment*
broiler chicken	*improving Bird Welfare*
	improving Poultry Welfare
	smart agriculture
	electronic Chickens
	robot for livestock breeding
	robotics in agriculture

Source: study authors

frequent and the other terms were generally dependent on it (e.g. "smart agriculture" should have the word "poultry" to determine the broiler production system). Furthermore, the search areas were determined (Computer Science, Agricultural and Biological Sciences, Engineering, Environmental Science, Science Technology Other Topics, Robotics or Automation Control Systems) and keywords that exclusively delimited the productive area of broiler chickens were included through of the NOT clause (ex. NOT TITLE-ABS-KEY (beef AND cow)). Finally, using advanced search tools, "queries" were created and the search period was determined from 2014 to 2024:

1 Scopus: *(TITLE-ABS-KEY (robo*) AND TITLE-ABS-KEY (poult* OR "broiler chicken") AND NOT TITLE-ABS-KEY (beef AND cow) AND NOT TITLE-ABS-KEY (dairy AND cow) AND NOT TITLE-ABS-KEY (pork) AND NOT TITLE-ABS-KEY (fish) AND NOT TITLE-ABS-KEY (hens) AND NOT TITLE-ABS-KEY (hen) AND NOT TITLE-ABS-KEY (ovo) AND NOT TITLE-ABS-KEY (egg*) AND NOT TITLE-ABS-KEY (pig) AND NOT TITLE-ABS-KEY (cattle) AND NOT TITLE-ABS-KEY (breast) AND NOT TITLE-ABS-KEY ("cutting industry") AND NOT TITLE-ABS-KEY ("multi-conference") AND NOT TITLE-ABS-KEY (conference) AND NOT TITLE-ABS-KEY ("La Plata") AND NOT TITLE-ABS-KEY ("gene") AND NOT TITLE-ABS-KEY (gizzerosine) AND NOT TITLE-ABS-KEY (evisceration) AND NOT TITLE-ABS-KEY (captain) AND NOT TITLE-ABS-KEY (litter) AND NOT TITLE-ABS-KEY (fluorescence) AND NOT TITLE-ABS-KEY (biochar) AND NOT TITLE-ABS-KEY (vegetation) AND NOT TITLE-ABS-KEY (dissection) AND NOT TITLE-ABS-KEY (antibiotic*) AND NOT TITLE-ABS-KEY (multiresidue)AND NOT TITLE-ABS-KEY ("renewable energy") AND NOT TITLE-ABS-KEY (penoxsulam) AND NOT TITLE-ABS-KEY (proteomics) AND NOT TITLE-ABS-KEY (digestion) AND NOT TITLE-ABS-KEY ("passive cooling") AND NOT TITLE-ABS-KEY (electricity) AND NOT TITLE-ABS-KEY (smallholder) AND NOT TITLE-ABS-KEY (nanotubes) AND NOT TITLE-ABS-KEY (pyrolysis) AND NOT TITLE-ABS-KEY (pollution) AND NOT TITLE-ABS-KEY (beans) AND NOT TITLE-ABS-KEY (dydrolysis) AND NOT TITLE-ABS-KEY (fertili*) AND NOT TITLE-ABS-KEY (reared) AND NOT TITLE-ABS-KEY (molecular) AND NOT TITLE-ABS-KEY (wastewater) AND NOT TITLE-ABS-KEY (carinata) AND NOT TITLE-ABS-KEY ("agricultural organic")AND NOT TITLE-ABS-KEY (nanoparticles) AND NOT TITLE-ABS-KEY ("Gel 95") AND NOT TITLE-ABS-KEY (jimny*) AND NOT TITLE-ABS-KEY (organic)AND NOT TITLE-ABS-KEY (recall) AND NOT TITLE-ABS-KEY (cilacap)) AND PUBYEAR > 2014 AND (LIMIT-TO (SUBJAREA,"ENGI") OR LIMIT-TO (SUBJAREA,"COMP") OR LIMIT-TO (SUBJAREA,"AGRI") OR LIMIT-TO (SUBJAREA,"ENVI") OR LIMIT-TO (SUBJAREA,"MATH"))*

2 Web of Science: _ALL=(robo*) AND ALL=(poult* OR "broiler chicken" or “fowl”) NOT ALL=(beef AND cow) NOT ALL=(dairy AND cow) NOT ALL=(pork) NOT ALL=(fish) NOT ALL=(pig) NOT ALL=(hens) NOT ALL=(hen) NOT ALL=(cattle) NOT ALL=(ovo) NOT ALL=(egg*) NOT ALL=(pig) NOT ALL=(cattle) NOT ALL=(breast) NOT ALL=("cutting industry") NOT ALL=("multiconference") NOT ALL=(conference) NOT ALL=("La Plata") NOT ALL=("gene") NOT ALL=(gizzerosine) NOT ALL=(evisceration) NOT ALL=(captain) NOT ALL=(litter) NOT ALL=(fluorescence) NOT ALL=(biochar) NOT ALL=(vegetation) NOT ALL=(dissection) NOT ALL=(antibiotic*) NOT ALL=(multiresidue)NOT ALL=("renewable energy") NOT ALL=(penoxsulam) NOT ALL=(proteomics) NOT ALL=(digestion) NOT ALL=("passive cooling") NOT ALL=(electricity) NOT ALL=(smallholder) NOT ALL=(nanotubes) NOT ALL=(pyrolysis) NOT ALL=(pollution) NOT ALL=(beans) NOT ALL=(dydrolysis) NOT ALL=(fertili*) NOT ALL=(reared) NOT ALL=(molecular) NOT ALL=(wastewater) NOT ALL=(carinata) NOT ALL=("agricultural organic")NOT ALL=(nanoparticles) NOT ALL=("Gel 95") NOT ALL=(jimny*) NOT ALL=(organic)NOT ALL=(recall)NOT ALL=(cilacap) AND (publication date > 2014–>01-01) AND Refined By:Research Areas: Agriculture or Engineering or Computer Science or Science Technology Other Topics or Robotics or Automation Control Systems_

The Scopus database returned 69 documents and Web of Science 31; a duplication analysis was performed in the R programming language using the *mergeDbSources* package and resulted in the exclusion of 10 articles; in the period (2014–2024) there was a growth rate of publications of 31.8%; an average of 3.81 publications per year; and a total of 359 related authors (Fig. 3). Using the *biblioAnalysis* package (R language), several metrics could be analyzed. The predominant document types found were conference articles (48.89%) followed by full articles (41.11%) (Table 7).

Table 7 Articles found and their types quantified

Type	Amount
Article	37
Book chapter	2
Conference paper	44
Meeting abstract	2
Proceedings paper	2
Review	3

Source: study authors

Most publications were carried out in China (17 articles, 32%), followed by the United States (9 articles, 17%) and the United Kingdom (5 articles, 9%) (Fig. 4 and 5). All of these countries have a high level of investment in technology and innovation, especially in agriculture and the food industry (Zhu and Liu 2020; Khelfaoui et al. 2020). Part of this investment is related to funding research that relates poultry farming to automation and robotics through strong collaboration between universities, research centers, and industry, promoting innovation and the application of research in real scenarios, particularly in the area of Precision Livestock Farming (PLF) (Rowe et al. 2019). In addition, these countries have large and well-established poultry industries, which drives the need to increase production efficiency due to the high demand for food and at the same time promotes the development of new technologies. Several studies (Essien and Job 2024; Özentürk et al. 2024; Sajid et al. 2024; Kopler et al. 2023; Ren et al. 2020) explain how robotics research in these countries is developed. In the US, the focus on agricultural robotics has been primarily on perception and reasoning capabilities (identifying objects, assessing product quality, and monitoring animal growth and

Fig. 3 Summary of results obtained using the *biblioAnalysis* package. Source: study authors

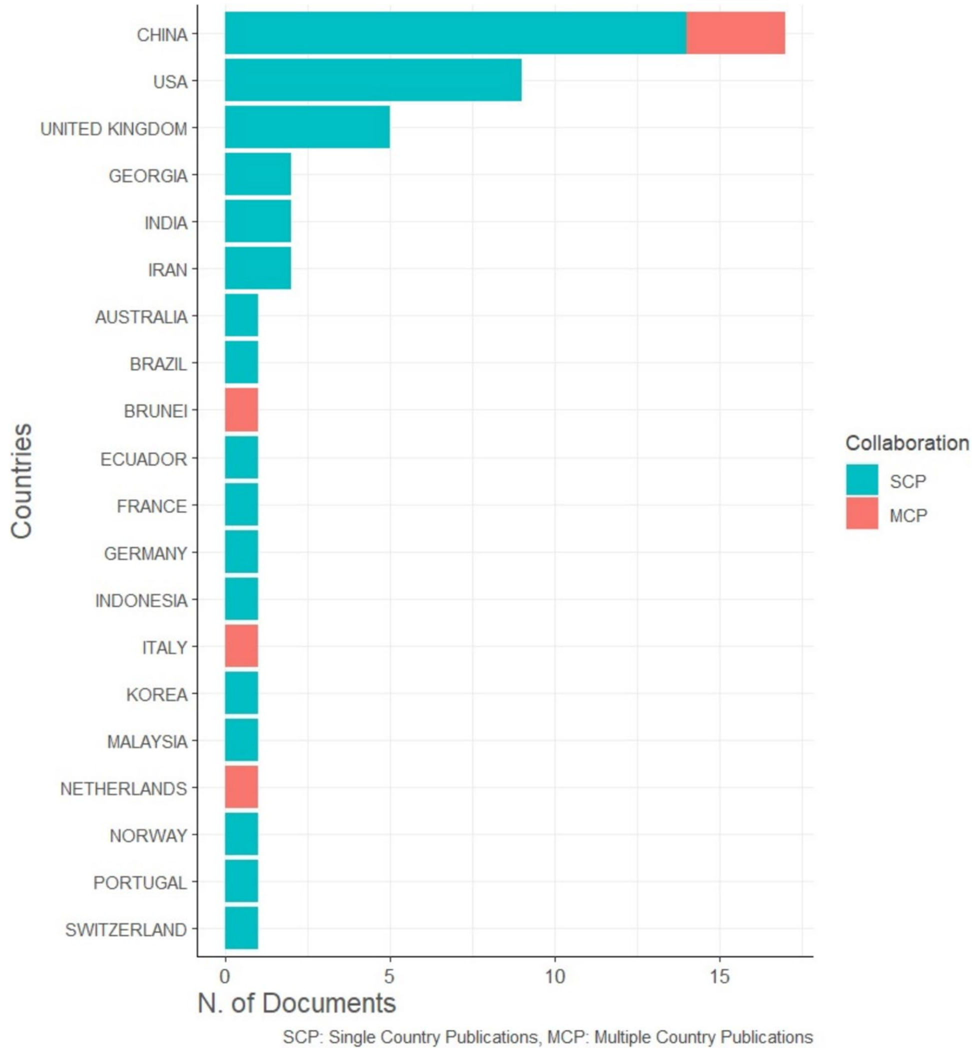


Fig. 4 Scientific production by countries. Source: study authors

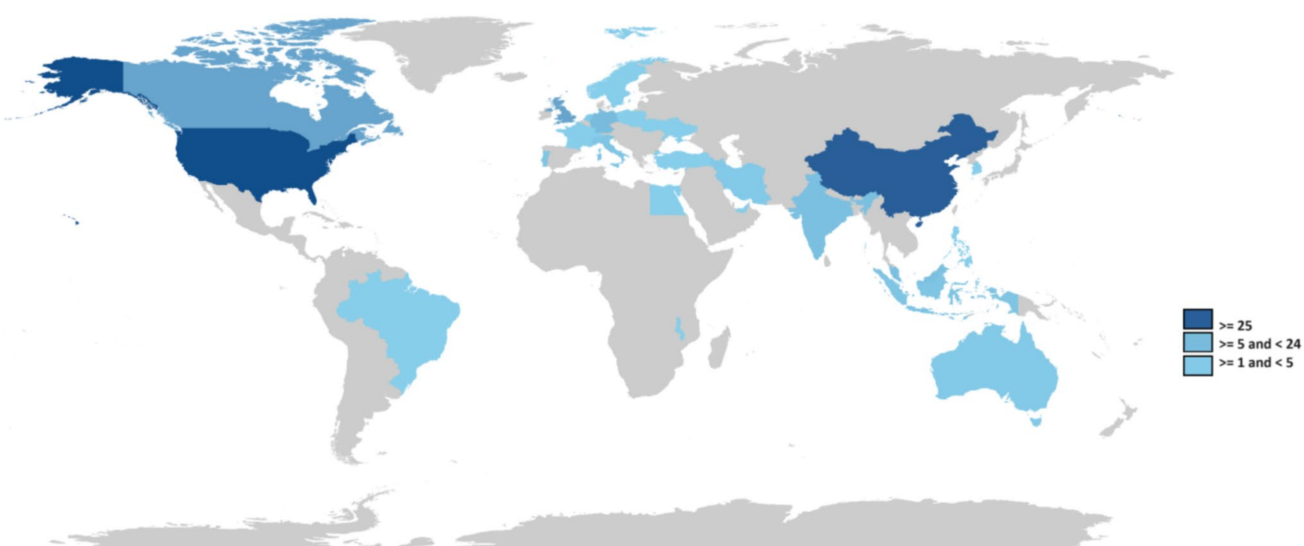


Fig. 5 Geographic distribution of publications by countries. Source: study authors

development). The UK has been exploring the use of robotics in poultry farming with a strong emphasis on animal welfare and sustainability, where robotic applications not only aim to improve productivity but also improve animal welfare through improved environmental monitoring and disease control. China's approach to robotics in poultry farming is characterized by a systems approach, focusing on the interactions of automated tasks to achieve high efficiency in the management of the entire poultry farm, with an emphasis on creating intelligent systems that can manage multiple aspects from environmental conditions to bird health.

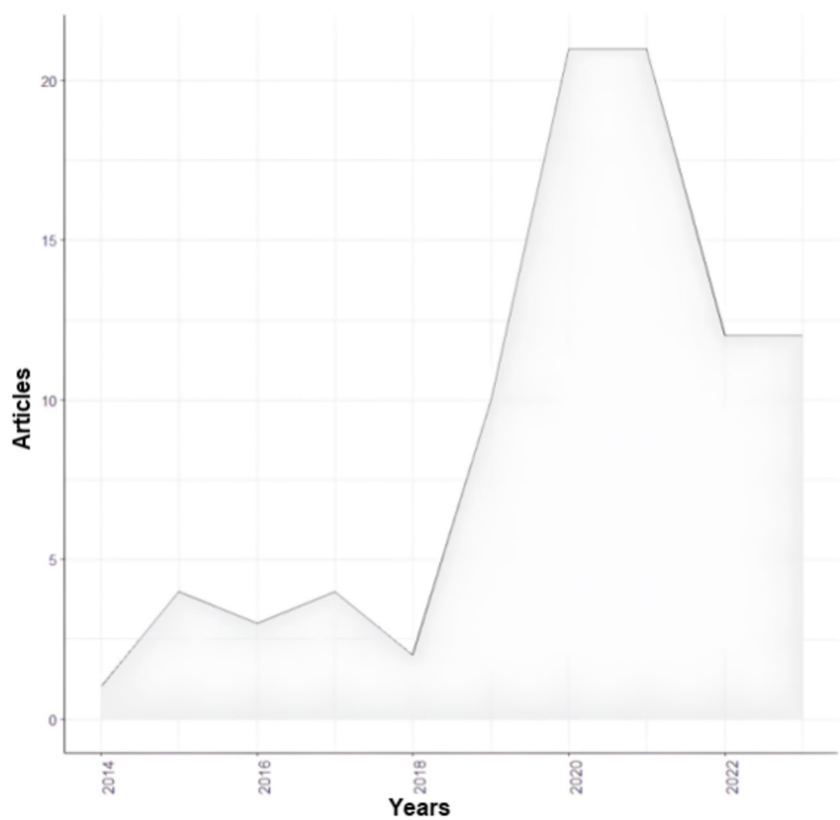
Most of the publications were published recently (last five years) and between 2014 and 2018 only 14 works were published and between 2019 and 2024, 76 were published (an increase of 442.86%) (Fig. 6). This fact can be attributed to several factors such as: technological advances in robotics, artificial intelligence and sensor technologies have made these innovations more accessible and applicable to poultry farming (Sajid et al. 2024; Shi et al. 2024; Nandhini et al. 2024); demand for efficiency where the growing demand for sustainable food and the need to increase efficiency in poultry production have created a conducive environment for research and innovation (Kopler et al. 2023; Batuto et al. 2020; Astill et al. 2018); changes in agricultural practices in which more technological and automated implementations have occurred through incentives and research results from universities and research institutions (Essien and Job 2024; Shi et al. 2024; Ozenturk et al. 2024; Ren et al. 2020); and government and financial support in agricultural research, promoting specific programs for innovation in robotics in poultry farming (Sajid et al. 2024; Fountas et al. 2020).

The articles listed several key words, the most referenced being: agricultural robots, agriculture, animals, robotics and poultry (Fig. 7).

The main themes that guide most of the research are: agricultural robots, agriculture and animals and corroborate most of the research reports by other authors (Özentürk et al. 2024; Essien and Job 2024; Cheng et al 2023). Subsequently, other research uses technologies such as computer vision (camera and image processing), artificial intelligence (machine and navigation) and the most important themes are: pattern recognition, mobile applications and animal behavior (Fig. 8). This is evident in the research of computational systems that work in technical relation with robots as in the published works of Essien and Job (2024), Sajid et al. (2024), Cheng et al. (2023), Fei et al. (2023), Dennis et al. (2020) and Feng and Wang (2020).

Figure 9 shows the distribution of how robotics research is organized in poultry production. It is understood that the term agricultural robots is inclusive of the term animals and, associated with it, is the term poultry. Based on this term, searches for robotic terms are constructed and technological tools are used, the main ones being: artificial intelligence, computer vision and internet of things.

Fig. 6 Publications per year, temporal flow of publications on the chosen topic. Source: study authors



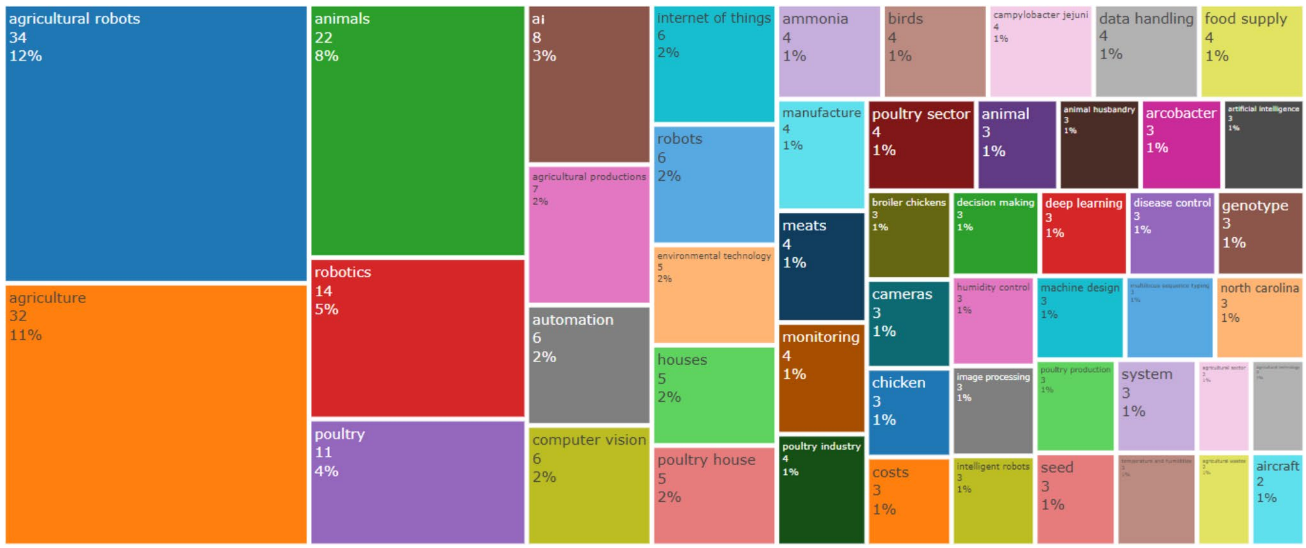


Fig. 7 Keywords most referenced in articles. Source: study authors

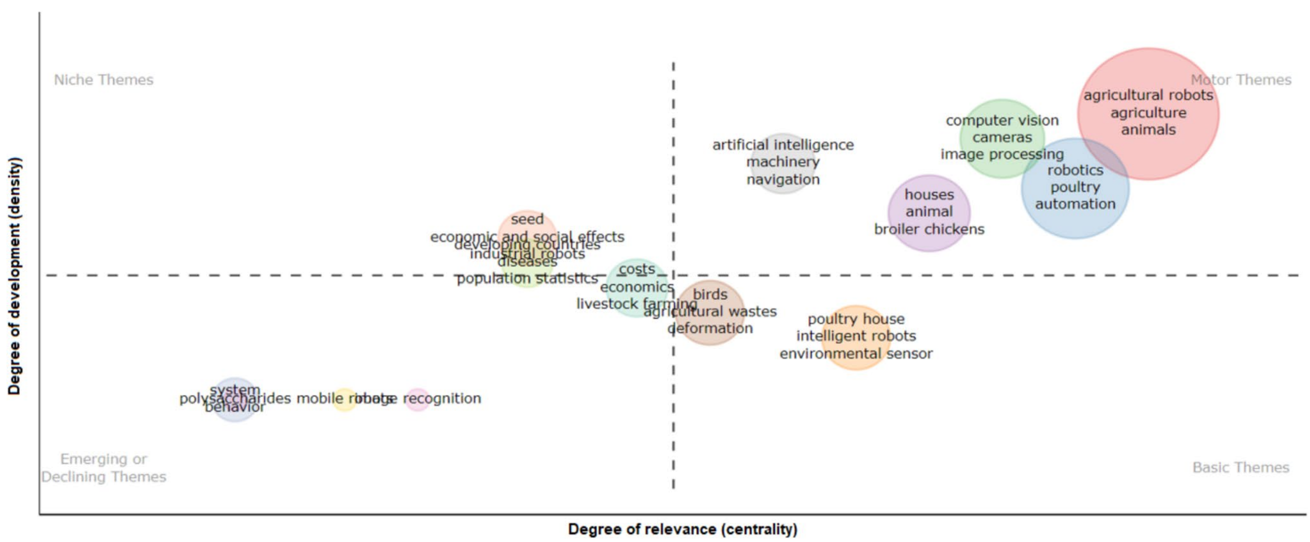


Fig. 8 Distribution by search trend. Source: study authors

Most influential research results in technology and robotics in poultry farming and its ambience

Table 8 presents a set of the most recent and influential articles on robotics in poultry farming, including technologies that are related to robotic systems as they ensure their operation.

Discussions

Understanding the flaws in poultry farming and at the same time adding value (increasing profitability by reducing losses) is one of the main motivations for using technologies in production systems. Authors such as Melak et al. (2024), Abreu et al. (2020) and Mansilha et al. (2019) complement by stating that technologies can point out production deficiencies, allowing losses to be understood.

Robotics is one of these technologies and is currently present in chicken production through various robots (Spoutinc 2016; Gasmetric 2016; Vroegindeweij et al. 2018; Ren et al. 2020; Lavicole Robot 2020). These robots can perform handling and monitoring activities, but have not yet developed all of their high-performance capabilities, as they still have limitations, as reported by several authors in high-performance communication capabilities (Ren et al. 2020).

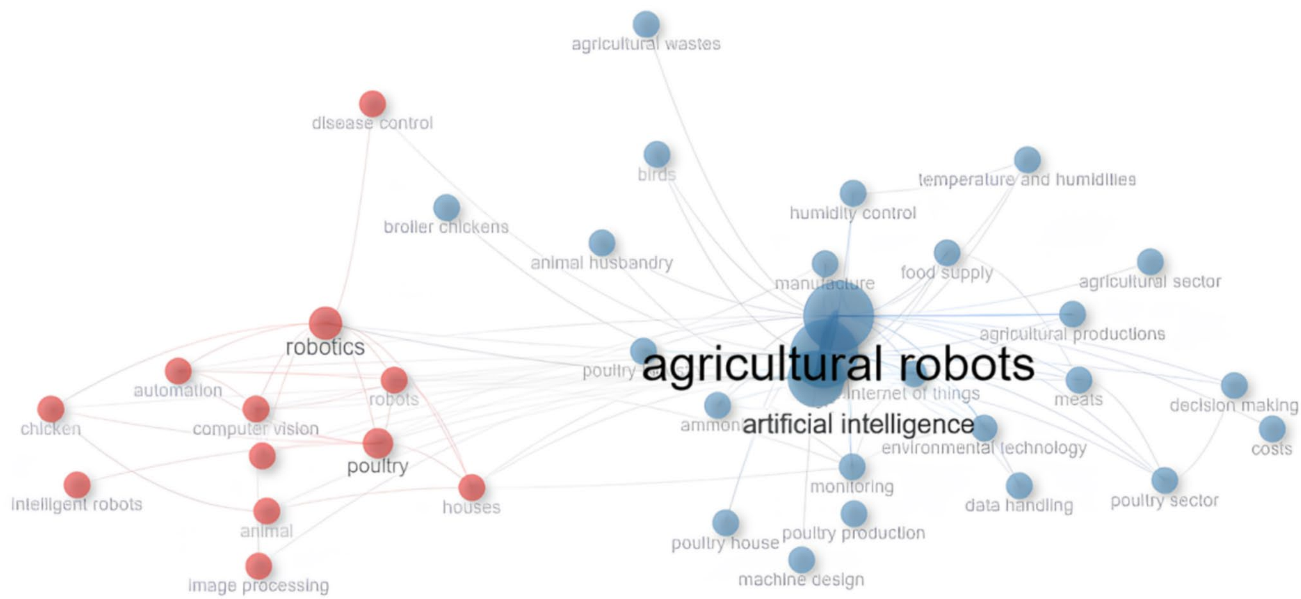


Fig. 9 Clustering of searches by similarity. Source: study authors

Research has evolved in this direction in order to meet these capabilities and Raja (2024) states that commercial robots that work in poultry farms have different technological and operating characteristics. The three analyzed robots (ChickenBoy, Octopus Poultry Safe and SPOUTNIC) highlighted these differences in several aspects (involving their functionalities).

The animal environment incorporates factors of the thermal environment that directly influence poultry farming and that requires attention due to the critical nature of the production system. Due to this criticality, current robots do not have a unique or standardized architecture. Each production environment requires a specific configuration of robots (Raja 2024) which need to be adapted to the type of work to be performed in order to make obtaining environmental data more accurate and, subsequently, assertive decision-making.

Sensors are used to detect the levels of environmental variables and understanding what the minimum and maximum limits are, during the complete breeding cycle, are fundamental. Several authors (Li et al. 2023; Melak et al. 2024) disagree on several points about the variability between the variables, with close or long values being presented, which is why it is important to understand what the ideal values are for all the production system (including weekly variability) and also the strain used in the production chain.

Bibliometric analysis made it possible to select and understand the main published technologies that are used in poultry farming robotics. The articles describe how robotics is directly associated with automation in the broiler environment and present computer vision as the most frequent technology; More general articles, which describe poultry farming associated with the production system, poultry management and the production sector itself, present artificial intelligence and the internet of things as the main technologies associated with robotics. This corroborates authors such as Xiang, Wang (2023) and Tang et al. (2023) who state that the use of computer vision goes beyond perspectives including modeling three-dimensional (3D) vision techniques associated with deep learning artificial intelligence models. Therefore, the prospects are that computer vision modeling will include 3D structural lighting techniques in future work using range detection and lighting systems with technologies such as LiDAR (Light Detection and Ranging) and monocular depth.

Conclusions

Robotics in poultry farming, despite presenting commercial technological implementations, still demonstrates challenges that require further evolution and development, particularly in high-performance communication. The intelligent communication system in poultry production integrates the Internet of Things (IoT), big data analytics, machine learning, and automation to optimize production processes, ensure animal welfare, and enhance efficiency. It is recognized that the environment in poultry farming remains a critical factor, and robotics can address this issue; however, high-performance communication must be

Table 8 Most influential articles in the study

Author	Country	Study subject	Main results
Batuto et al. (2020)	Philippines	Poultry Management System, an IOT system that automates the process of giving feeds and water to poultry animals with data from various data sources also enabling robotic systems	Upgrading poultry businesses that saves time and effort due to automatic management and real-time data dashboard visualization
Balthazar et al. (2024)	Brazil	Understand whether the speeds of movement of a robot cause variation in Escape Distance (ED) and their implications for animal stress	Low speeds shown low ED results, it did not show enough ED to move the animals away from their path of travel, causing bumps and collisions; High speeds showed higher ED in all breeding phases, but showed ED with no bumps and collisions
Bui et al. (2024)	Australia	Cyber threat intelligence sources and techniques in smart farming ecosystems	Questions how cyber threat intelligence (CTI) techniques should be used in smart farming infrastructures (SFIs) through a taxonomy called Chief Information Security Officer (vCISO) due to the main productive focus, size and resources of the data set and use of Artificial Intelligence techniques in order to guarantee the integrity of the agricultural ecosystem and the security of the global food supply chain
Chen et al. (2023)	China	Design and simulation of a cage-type chicken detection robot for the complex environment of cage farming	Defines a kinematic model, with values for uniform acceleration and deceleration movement, energy consumption and the detection of chickens along the way
Cheng et al. (2023)	China	It presents various research status and applications of agricultural robots and discusses the benefits and challenges involved in their applications	Directional indications regarding research trends related to agricultural robots are presented
Dennis et al. (2020)	UK	Presents a study on the behavior of commercial broiler chickens in response to a mobile robot	Showed that running a mobile robot among a flock of broilers is possible for between 3 and 37 days in a cycle and causes limited disruption to bird behavior
Essien and Job (2024)	Nigeria	Identify current advances, problems and development prospects of robotics in poultry farming, examining existing challenges, solutions and innovative research, including robot-animal interactions	The robots analyzed in the study not only demonstrate effective implementation on farms, but also have potential for ethological research into collective and social behavior, which could in turn drive better integration into industrial agriculture, with improved productivity and enhanced animal welfare
Fei et al. (2023)	China	Real-time recognition study of egg-collecting robot using YOLOv5s models for free-range egg detection based on a self-researched mobile robot platform	The results showed that the accuracy and recall rates of the improved model were satisfactory because the improved model can accurately detect eggs in houses poultry and can well meet the demand for real-time egg detection
Feng et al. (2020)	China	In order to the efficiency security of disinfection for livestock breeding, a disinfecting robot system and intelligent disinfection mode were researched	As demonstrated in the test results, the average diameter of the drops at ideal distances for spraying was correctly defined, as well as the average deposition density, determining completely satisfactory results regarding the need for disinfection
Fountas et al. (2020)	Greece	A systematic literature review was conducted on research and commercial agricultural robotics used in crop field operations	It shows that the most explored robotic systems were related to harvesting and weeding, while the least studied were disease detection and seeding robots
GASMETRIC (2016)	USA	Robotic system in poultry farming that allows collection and analysis of environmental data (gases such as ammonia and carbon dioxide) in real time	Presented a robot that can analyze the condition of the presence of gases in the air by using it with animals, indicating the values for later analysis
Kopler et al. (2023)	UK	Farmers' perspectives on the benefits and risks of Precision Livestock Farming (PLF) in the EU pig and poultry sectors to understand how PLF implies new methodologies, technologies and regulations at farm level, as well as changes in quantified business models	It presents as results the investigation of farmers' attitudes and concerns about the acceptance of technological solutions in the livestock sector must be fully incorporated into any technological development

Table 8 (continued)

Author	Country	Study subject	Main results
Lavicole Robot (2020)	France	Rabaud is a French manufacturer of agricultural, forestry, wine-growing, green space and public works equipment that has built a manual robot for disinfecting poultry houses	It presents a set of self-propelled and radio-controlled cleaning machine technologies designed for poultry houses, chicken coops through the use of manual work robots
Li and Zhou (2021)	China	Presents a study on robotic inspection planning in a large chicken coop can effectively reduce the spread of diseases, reduce labor and reduce costs	Presents split method to split the robot's inspection road into several sections, and uses the control point method to plan the robot's motion state in the shortest time under each road section, so as to ensure that the robot's overall inspection time is largely reduced, and greatly improves the inspection efficiency of the robot in the stacked cage chicken house
Lin et al. (2023)	China	In order to solve the traditional disposal process complicated, manual cannot involve part of the hidden places, single function and other problems, we designed an integrated risk garbage transfer and disposal robot	The robot was able to automatically identify and transport garbage, spray disinfectant and autonomously navigate for unmanned disposal using an integrated control system composed of ultrasonic obstacle avoidance technology
Nandhini et al. (2024)	India	Development of a line-guided robotic car for precision monitoring of poultry farms using IoT to ensure real-time monitoring of environmental conditions, which is critical for bird welfare	Internet connectivity facilitates real-time data exchange, supporting data-driven decision-making for sustainable poultry farming practices as it represents a comprehensive approach in integrating advanced technologies to address the vital importance of poultry farming in ensuring global food and nutrition security
Özentürk et al. (2024)	USA	Review article that presents the current advances and limitations in robotics in poultry farming and describes future directions of development, including robot-animal interactions, in which the applications of robots in different areas were researched, from environmental monitoring to disease control, ground egg collection and animal welfare	The results demonstrate that robots not only have effective implementation on farms, but also have potential for ethological research on collective and social behavior, which can in turn drive better integration into industrial agriculture, with improved productivity and improved animal welfare
Poultry Patrol (2019)	USA	Poultry Patrol is a robotics company serving the poultry industry by providing a robotic solution that increases bird movement, sends notifications of feed spills and other water leaks, plows barn bedding, and reports barn-wide mortalities	Production of several autonomous robots that operate in poultry farming that use different technologies for monitoring, operating and maintaining the poultry farm
Ren et al. (2020)	China	Research review in agricultural robotics applicable to poultry production providing a comprehensive review of published research and development work, emphasizing robotics that enable machine capabilities	Notable results include the Octopus Poultry Safe (OPS) robot for autonomously sanitizing poultry houses, the PoultryBot for floor egg collection, and the Spoutnic for training chickens to move around
Rowe et al. (2019)	UK	Systematic review article of precision livestock farming in the poultry sector that assesses whether the technology is focused on improving bird welfare, aiming to provide an overview of the development of PLF technology in poultry farming and to investigate whether improving welfare has been the main objective of PLF development	The results indicate that PLF development has most commonly focused on broiler chicken farming, followed by laying hens, and mainly involves the use of sensors (environmental and wearable) and cameras
Sajid et al. (2024)	Pakistan	It assesses how the integration of robots and smart sensors into chicken farming increases production and operational efficiency by examining the latest developments and how they are revolutionizing the methods used in chicken production	Results point to the effectiveness of using smart sensors that provide real-time monitoring of feed efficiency, health metrics and environmental variables

Table 8 (continued)

Author	Country	Study subject	Main results
Shi et al. (2024)	China	Current status and future prospects of livestock and poultry farming robots through meticulous analysis of the deployment of these robots in various facets of the farming process, including automatic cleaning, inspection and feeding, showing their potential not only to improve operational efficiency but also to advance smart farming practices	This forward-looking analysis serves as a reference and inspiration for the continued modernization of the livestock and poultry industry, encouraging further research and development in this vital sector
Usher et al. (2017)	USA	A mobile robot system was developed and tested for operation in confined poultry houses through activities that ensure animal health and proper poultry house operation	The robot's ability to successfully navigate the house was analyzed, ensuring that there was no negative impact on animal welfare, successfully proving that the prototype system can achieve the desired goal of navigating a chicken coop environment
Vroegindeweij et al. (2018)	Netherlands	Evaluation of the performance of PoultryBot, an autonomous mobile robotic platform for poultry houses	The results demonstrate the validity of the PoultryBot concept and the possibility of autonomous egg collection from the floor in commercial poultry houses indicating that the application of intelligent autonomous vehicles in dense animal environments is feasible
Zhang et al. (2022)	China	An approach for path planning of autonomous feeding robots in smart poultry farms by optimizing path planning in this study, and the minimum energy consumption travel path planning algorithm was designed	The results of the experiment show that the approach proposed in this study is efficient for the proposed navigation model

Source: study authors

improved to facilitate effective decision-making regarding real-time monitoring of poultry farms.

The result is Smart Poultry Automation, which utilizes sensors, actuators, and IoT technologies to increase productivity, reduce operational costs, enhance animal welfare, and improve decision-making for farmers. Furthermore, the maturation of technologies (sensors, actuators, and software) has opened up new possibilities for research in robotics, leading to current trends that emphasize the use of computer vision, artificial intelligence, and the Internet of Things. Environmental monitoring is one of the potential research areas in robotic applications for broiler chicken production, but it is not prioritized among current robots, as research on handling techniques is more commonly found.

Research in agricultural robotics has demonstrated potential in precision livestock farming; however, challenges persist in developing intelligent machines for specific tasks, such as monitoring environmental conditions and chicken health. The real-time monitoring of environmental variables is achievable through the integration of IoT systems that assess animal comfort conditions, for example, based on the specific enthalpy of the air. It can also be concluded that countries with greater technological production capabilities, such as China and the United States, are able to conduct more extensive research in robotics. Finally, this article serves as a status report on robotics in commercial broiler poultry farming and as a foundational resource for research into environmental monitoring in poultry farming.

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Author contributions Glauber da Rocha Balthazar and Iran José Oliveira da Silva (Supervision, Project administration, Methodology; Analysis; Writing); Robson Mateus Freitas Silveira (Technical assistance and final review). All authors read and approved the final manuscript.

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Data availability The datasets generated during and/or analyzed during the current study are available in the GitHub repository: https://github.com/glauberbalthazar83/PoultryBibliometric

Declarations

Ethical committee approval This work is part of a research on robotics with broiler chickens that was submitted, analyzed and approved by the Ethics Committee on the Use of Animals of the Luiz de Queiroz College of Agriculture of the University of São Paulo, under protocol number 7364090322.

Consent to participate Informed consent was obtained from all individual participants included in the study.

Conflict of interest/Competing interests All persons gave their informed consent prior to their inclusion in the study and the authors declare have no relevant financial or non-financial interests to disclose.

Review articles: declaration Glauber da Rocha Balthazar is declared idea author for the article, who performed the literature search and data analysis, and who drafted and/or critically revised the work.

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